Hernan L, Dade-Robertson M.

Atmospheres of digital technology: wireless spectres and ghosts outside the machine.

***Digital Creativity* 2016, 27(3), 214-233.**

Atmospheres of digital technology: Wireless Spectres and ghosts outside the machine

Luis Hernan
j.l.hernandez-hernandez@ncl.ac.uk

Martyn Dade-Robertson
martyn.dade-robertson@ncl.ac.uk

School of Architecture Planning and Landscape
The Quadrangle
Newcastle University
NE17RU

0191 2085926

Abstract

This paper examines the atmospheres of invisible technologies in the built environment. Starting with the, often cited, notion of technologies of disappearance this paper suggest that, in the absence of physically tangible infrastructure, we understand and frame technologies through myths and historic forms of interpretation. Using the specific example of Wi-Fi networks the paper draws parallels between the operation and interpretation of modern wireless infrastructure and the spiritualism of the 19th century. Furthermore, it shows how through creative exploration, using a visualization device and a photographic method developed by the authors, perceptions of these invisible infrastructures and the spaces they occupy can be played with. The work acts as an extension and critique of the way wireless infrastructure is currently described and perceived and through playful exploration may lead to new types of technology and spatial design.

Keywords

Ubiquitous computing; pervasive computing; hertzian space; visualization; human computer interaction

1. Introduction

The late twentieth century and the early twenty-first century has been dominated by narratives of digital technologies, from the interweaving of digital and physical infrastructures of telecommunications (Graham and Marvin 2002), to discussions of the 'cyberspace' of the world wide web as a new sort of urban form (Dade-Robertson 2011). Contemporary discourses in, for example, human computer interaction highlight the embedded nature of technology in the built environment suggesting that digital technologies have become 'ubiquitous' and 'pervasive'. Furthermore, through ubiquity, it is proposed that digital technologies become invisible, in the terms of Michael Weiser, to "…*weave themselves into the fabric of everyday life until they are indistinguishable from it*" (Weiser 1999). Conversely, in architectural design there is a fascination with these technologies as they are revealed at their points of interface. Discussing the act of using a mobile phone to locate a restaurant, for example, Greenfield and Shepard. comment that:

> The transaction's very banality camouflages the elaborate information choreography involved in its success to say nothing of the dense infrastructure of servers and routers and transmission towers (Greenfield and Shepard 2007, 13).

Others have explored the limits and seams of pervasive digital technologies by highlighting, for example, the role of tuning and calibration in our interaction with devices and networks (Coyne 2010) and discussing interactions with urban technologies in terms of territories, fields and thresholds (Dade-Robertson 2013), ambience (Ishii et al. 1998) and the tactical use of gaps and errors in digital infrastructure (Benford, Crabtree, and Flintham 2006). These discussions reveal a materiality of technology beyond the physicality of the digital objects themselves (whether phones, optical cabling or mobile phone masts) and suggest an alternative perception of space mediated by our interactions with technology. What is sometimes forgotten in these narratives of newness and transformation, however, is that these objects are often

interpreted within cultural frameworks which are already established. Bolter describes an essential feature of digital technologies as their capacity to remediate – i.e. to take existing media types and simulate some of their properties (electronic 'books', the 'desktop' interface etc.) (Bolter and Grusin 2000). If we extend this notion to space, then we have to understand that digital infrastructures can and do remediate spaces. In practice this remediation is revealed through tactics of interaction and modes of interpretation. A disappearing technology, in Weiser's terms, must, in order to serve its function, reveal itself through the narratives we tell about it or the moments where the cloak of invisibility drops (often at the point where it breaks).

This paper will examine one such pervasive technology of disappearance, namely wireless networks (Wi-Fi), and explore how, given the lack of tangible material presence, others have attempted to find ways of materializing them. These materializations have taken the form of visualizations and mappings of *Hertzian Space*, but are also to be found in the history of the discovery and manipulation of electromagnetic waves through their association with spiritualism, ghosts and spectres. The paper includes an account of a creative exploration of these notions of materializing wireless networks through the creation of a measuring device and adapting a photographic process which reveals their presence whilst drawing attention to the apparatus of production.

2. Wireless materiality

Wireless exchange protocols have become an increasingly prominent and ubiquitous technology. Not only because they constitute an invisible infrastructure, connecting a multitude of digital artifacts, but also because they have prompted a transformation in the way some people use space. This is attested by the countless stories of the pervasive influence of wireless signals on the social use of space, from coffee shops which become communications hubs because they have free Wi-Fi (Sevtsuk et al. 2009), or the huddles of laptop users in previously unused corners of the library because wireless

signal strength is strongest (Hill 2009; Hill 2012). Coyne (2010) places wireless exchange protocols in the same terms as Mumford did for the technologies of time-keeping. Mumford argued that time related technologies such as clocks and timetables, more than being designed to merely keep track of passing time are, in reality, technologies of synchronisation and coordination—they enable humanity to work to the same mechanical beat. Similarly, Coyne interprets digital devices as the means through which people tune their activities with one another. Wireless exchange protocols can be said to constitute a technology of alignment of social activities.

The interpretation of wireless exchange protocols as a technology of attunement, and their consequent implication for the construction and habitation of space, is also elaborated by Mitchell (Mitchell 1996) and extended to, not only include the technology of synchronicity, but also to affect the physical infrastructure and supply chains of whole cities. His thesis is based on what can be called the materialization of digital information, or as Weiser (1999) would call it *embodied virtuality*, where material and information are no longer separated. The key point in this evolution, Mitchell argues, is the development of ubiquitous wireless connections, which allow for a physical realm in which every constituent part can be, at least theoretically, networked. This revolution in materiality of digital information makes for cities where the patterning of wireless protocols is just as important as patterning of physical walls and built structures.

Despite its evident relevance to the tangible fabric of architecture, it is problematic to deal with wireless in terms of materiality. Traditionally, materiality has been used to describe the sensorial relationship that allows designers to gain knowledge of materials (Brownell 2014; Lillegerd 2007; Schön 1992). As a consequence, only entities with a consistent, tangible substance are thought to be material. Debates on the way in which design deals with an increasingly complex palette of material possibilities, ranging from smart materials designed at the molecular scale to invisible technologies,

have called for a revaluation of the notion of materiality itself. Inspired by the material possibilities afforded by material science, Manzini proposed the need to develop new ways of engagement that substituted for direct experience to provide designers with means to understand and act upon materials. In so doing, he proposed that in the absence of direct, material engagement with matter it is representations and language that are used to engage with emerging and complex new materialities (Manzini 1995).

Also relevant is the notion of *digital materiality*, which provides a framework to approach the materiality of invisible technologies. Leonardi (2010), for instance, argues that notions of materiality are often tied to an understanding of fixed features that transcend the time and space of usage. The capacity of invisible technologies, however, to constrain or afford human action suggest they can be considered as equivalent to more tangible materials. Such an understanding of materiality, however, is dependant on interaction. One invisible infrastructure can be more or less material to different users, depending on their context of use. This is parallel to the notion of *agential realism*, which challenges the notion that material entities precede interactions. Barad (2006) proposes the notion of intra-action to refer to the way in which individual entities do not have an immutable, transcendent substance. Rather, they are *constructed* by the set of material transactions. An example of this would be to talk of the flexibility of wood. In a traditional understanding of materiality, different types of wood *have specific mechanical properties*. This feature, however, can only be assessed through direct interaction — a craftsmen yielding the wood, or an engineer performing load testing to determine its flexibility instrumentally. Agential realism posits than the materiality of wood, as seen through its feature of flexibility, only exist when it is acted upon (Barad 2006; Kleinman 2013). Materiality is therefore an emergent feature, which is contingent on transactions with other materials and through human interaction.

Measuring and representing wireless involves a series of transactions — the construction of a probe to measure signal strength, logical processes to transform values into a visible pattern, a choreography to move the probe in space. Following notions of agential realism and digital materiality, we propose that these transactions *construct* the materiality of wireless, and aim to position the process of representation as a form of speculative design (Dunne and Raby 2013) which deals with the emergent materialities of wireless. In this paper, we develop a creative practice approach that adapts tools and techniques developed in explorations by others to engage with the material transactions in representing wireless. We shape the exploration through the historical guiding metaphor of wireless as spectre, a notion which emerged in the 19th century as a result of the introduction of the first generation of wireless technologies for telegraphy and radio broadcast. This allows us to create allusive images, to contribute to renewing notions of how wireless can be integrated in the design of artefacts and spaces.

3. Analogue and Analogy: materialities of wireless infrastructure

Hertzian Space, as we describe it here, constitutes the wide spectrum of communication protocols which make use of electromagnetic fields. Technologies of Hertzian Space were developed as early as the 19th century, and now form part of the fabric of our technological world in a wide range of telecommunication technologies including Wi-Fi. An important feature of Wi-Fi is that it sets a series of protocols for the physical and technical implementation for the wireless exchange of information, and relies on the translation of information into analogue signals broadcasted in electromagnetic waves.

Revealing the materiality of Wi-Fi, along with other wireless technologies, has influenced a number of projects which set out to ‘visualize the invisible (“Observatorio, Clara Boj and Diego Diaz” 2008; Husbands 2013; British Council 2014; Chan 2013; De Vicente, Harger, and Perello 2012). Most

notably the Touch Research Group (Martinussen 2012), an interdisciplinary mix of computer science, human-computer interaction researchers and industrial designers, gathered to research NFC (Near Field Communication) protocols, and to create design narratives that draw from cultural enquiry and design exploration. In one notable and highly published project (Arnall 2011), *Immaterials*, an instrument was constructed to map signal strength from Wi-Fi signals in the city of Oslo, projecting the results as a (sort of) physical bar graph. An Arduino microcontroller is connected to a wooden rod fitted with 60 led points. The instrument periodically scans for a pre-established Wi-Fi network, retrieves its Received Signal Strength Index (RSSI) and remaps the results on to the LEDs strip. The higher the number of LEDs which light up, the stronger the signal. The device is then moved across the space by an operator who holds it vertically whilst slowly walking in a straight line. This process is registered using long exposure photography, which involves opening the camera shutter for long periods of time so that moving sources of lights are registered as a continuous trail (Martinussen 2011).

The images presented in Immaterials convey a notional Wireless landscape that co-exists with the built environment. The series of photographs taken in the city of Oslo depicts wireless networks as a landscape of blue light points. The generated landscapes isseen to grow and shrink, with buildings caused byshadows in the Wi-Fi signal. The project received an enthusiastic response from technology blogs, having been covered by multiple online publications (Sterling 2011; Holmes 2011; D.B. 2011). Interpretations in the photographs vary across articles, but they converge on the notion that the observed structures are physical representation of wireless coverage, likening the process to the cartographic exercise of surveying and map-making. In some cases, the representations are also interpreted as revealing the terrain of Wi-Fi networks (Sterling 2011). These interpretations are curious since the visualisations do not provide a direct spatial corollary in the way that for example, previous work does for the geometry of fields in RFID tags (Nordby

2010; Nordby 2011). They are, rather, data extrapolations – measurements of signal strength physicalized on location, rather than topographies.

These projects deal in the language of mimetic, indexical representation. Arnal describes the process followed in Immaterials as follows: '*The project set out to expose some of the phenomena and mechanisms of technological infrastructures*' (Timo Arnall 2013). In talking about the instruments and techniques developed for the project, Martinussen talks of '*instruments and techniques that can reveal qualities of wireless networks that we cannot normally see*' (Martinussen 2012, 235). Another project representing WiFi is described by it authors as taking '*"pictures" of spaces illuminated by wireless radio signals, in much the same way that a traditional camera takes pictures through visible light* (Haque, Sjölen, and Somlai-Fischer 2007). This comment is made in a context where representations are proposed to provide the means to increase technological literacy, thus being able to comment and act on the changes technology bring about to everyday life. In describing work visualising technological devices and infrastructure, Bridle considers: '*Those who cannot perceive the network cannot act effectively within it, and are powerless. The job, then, is to make such things visible*'.

Contemporary notions of materiality suggest an alternative approach. In the previous section, we have followed notions of agential realism in proposing that representations can be thought of as tools by which designers speculate on potential materialities for wireless. This implies that the materiality of wireless is not a fixed property which can be simply recorded and revealed in representations. In its context of use, for instance, the materiality of wireless infrastructure is constructed through the interaction between electromagnetic signals, the device, the access point and the specific user. Likewise, the materiality represented is constructed by the configuration of the probe, the algorithm used to interpret data, and the metaphor used to translate data into a visible pattern. Recognising these layers of materiality allows us to think of the process of representation not as a way of documenting the operational

parameters of wireless infrastructure, but as a way of speculating on alternative materialities. Consciously tuning different elements of the representation process allows us to produce new materialities of wireless, which invite us to think of potential '*poetic and multi-layered coupling of electromagnetic and material elements'* (Dunne 2006, 121).

An alternative to exploring the concatenated registers of wireless materiality, is to dissect the analogies which enable their representation. For example one analogy often cited in understanding and mapping into the visible is the notion of wireless as landscape, first advanced by William J. Mitchell. In Me++ he wrote that *'Every point on the surface of the earth is now part of the Hertzian landscape(…) The electromagnetic terrain that we have constructed (…) is an intricate, invisible landscape'* (Mitchell 2003, 55). This metaphor is clearly present in the work of the Touch Research group. Alternatively, we may look how electromagnetism was understood, early in its development in the 19th century, as spectre. By examining this alternative metaphor, we can begin to uncover alternative material pathologies for wireless technologies

3.1 Narratives of wirelesses

In discussing the place of television within American culture, Jeffrey Sconce puts forward the thesis that electronic technologies lend themselves naturally to be conceptualized as '*either uncanny electronic agents or as gateways to electronic otherworlds*' (Sconce 2000). Due to their nature, Sconce argues, electronic media create an artificial sense of immediacy and liveness—in some cases, eliciting a schizophrenic feeling of personal communication and physical immediacy to what is being transmitted. Quite naturally, such properties invest a character of sentience and animation to electronic artifacts.

While this can be said to pertain to all electronic technologies, there are specific traits of wireless technologies that invest them with mystical, fantastic and spiritual narratives.

Wireless technologies offer connections to specific cultural analogies in terms of their operational appearance and disappearance. In this section, we discuss three central themes which have guided our exploration in the design of the instruments and choreographies.

3.1.1 Disembodiment

As wireless technologies have allowed the separation between information from the physical means of propagation, it comes as no surprise that the technology has invited speculations on the possibility of re-establishing a connection to departed human consciousness. Sconce sums up an argument on how the technical basis for simulated immediacy in wireless media gave way to a new basis from which to understand consciousness and communication:

> Whereas messages had previously been more or less grounded in the immediate space and time of those communicating, the wondrous exchanges of the telegraph presented a series of baffling paradoxes. The simultaneity of this new medium allowed for temporal immediacy amid spatial isolation and brought physical connection in spite of physical separation' (Sconce 2000).

The capacity of wireless to transport human consciousness, in the form of written thoughts, through space also imbues it with the illusion of own consciousness and animation, as described in the next section.

3.1.2 Otherworldliness

The promise of human consciousness untethered from the chains of bodily materiality pervaded the mystical cultures of the 19th century, and evolved to take into account herzian waves. The prospect of a different, unattainable world which hertzian waves made possible was founded on the concept of

ether. The theory of luminiferous ether was proposed to reconcile the discovery of waves with the model of Newtonian classical physics. Waves are conceptualised in physics as periodic disturbances in the dimensions of space and time. During the late 19th century, it was widely believed that any wave would need a medium for its propagation. The theory stood when applied to sound, light or electromagnetic waves operating in the earthly atmosphere as air acted as medium to propagate the disturbance. However, the model failed when applied to explain how light travelled through space from the sun to the earth without the presence of air (Lodge 1909). Therefore, it was conjectured, there must be a medium in deep space which allowed for the propagation of light waves. Clerk Maxwell defines the etheric medium as '*a material substance of a more subtle kind than visible bodies, supposed to exist in those parts of space which are apparently empty*' (Maxwell 1891). It has been suggested that the term bears some connection to the notion of ether as developed in Greek mythology, which constructed a duality between the air which common mortals breathed, and the aether, the refined fire of the empyrean breathed by the gods.

The development of ether physics during the late 19th century could merge discussions of the physical events of wave propagation and the discussion on the existence of the spirit world as special cases of vibration within the same medium. The adoption of etherical theories to account for scientific as well as mystical matter should be understood within the context of the reaction against materialism, especially in Physics during the late 19th century. Materialism refers to a philosophical school which establishes matter as the basis to explain any phenomenon in the universe, including the emergence of human consciousness. As a consequence, any event in the world can be assessed and described through the senses and by following a scientific methodology. The materialist position was largely promoted by the industrial revolution in the Victorian period, producing a counter movement within science and philosophy that sought to re-establish the paradigm of a unified cosmos that allowed for the coexisting of matter and spirit (Bowler 2010).

A case in which the sense of otherworldliness in etheric theories is made manifest in wireless technologies can be found in DX fishing, a practice whereby people would tune into wireless frequencies with the hope of stumbling upon a ghostly transmission (Blanco and Peeren 2013). As pointed out by Sconce, the fascination for wireless and its mystical possibilities stems not so much from its content, but from the mystical narratives that its technical basis invites: "*It's not the substance of communication without wires, but the fact of it that enthrals*" (Sconce 2000, 65). This observation resonates perfectly with the notion of media theorist McLuhan, who most famously advocated for the importance of the medium over the actual content in understanding the cultural and social affects of media (McLuhan and Fiore 2011).

3.1.3 Animated Agency

The established connection between the ether and the disembodied consciousness also prompts an additional set of fantasies and analogies regarding the possibility of independent consciousness in wireless technologies. Not only is wireless imagined as carrying consciousness from the realm of the spirit world, but also electronic artefacts are imagined as exhibiting a consciousness of their own. The logic behind this narrative seems to be connected to metaphors of life, stream and flux being used to describe electricity and wireless. Early tropes of wireless were based on, for instance, notions of fluids, which in turn had been used before to characterise the nature of human consciousness (Sconce 2000, 8). It follows, Sconce argues, that the cultural interpretation of electronic technologies is greatly shaped by the historical fact that such concepts are thought to be transmutable. Electricity is imagined as a life force that allows for the separation of consciousness and body.

Claims of transference of consciousness onto the electronic artefacts are especially observed in television. The configuration of television allows, for example, for liveness to be reinterpreted to include not only the voice of the dead, as in radio and telegraphy, but also the possibility of miniature worlds, identical to the real and fitted within a box. The ghost no longer uses the technology as medium to communicate with the living, but in fact dwell inside of it (Sconce 2000, 124).

4. Creating Wireless Spectres

These rich, predominantly 19th Century framings of wireless technologies still remain faintly present in discussions of modern Wi-Fi. The need (as demonstrated, for example, by the Immaterials project) to conceptualise Wi-Fi as physical territory, and the modern fears associated with electromagnetic sensitivity speak of a modern preoccupation and, perhaps, distrust of technologies which are central to the operation of our spaces but which are not present to our senses. To explore these ideas further we began to develop a project which would extend the *Immaterials* method, whilst reflecting on the cultural basis of wireless technologies and their '*untamed, subterranean reality'*.

To this end we created a machine we called a 'Kirlian' device (Figure 1-3), after the instrument designed by Semyon Dawidowicz Kirlian, an electrotechnician who discovered a photographic process which captures corona discharges around objects. The process was widely adopted in, so-called, paranormal investigation, linking the images it created to the capture of human aura (Ciesielska 2009). Unlike the device created for *Immaterials*, the Kirlian device aimed to visualise the strength of the Wi-Fi field spatially by associating, in three dimensions, signal strength with the colour of the light emitted.

An initial routine was written, using the Arduino Development Environment, to perform an active scan of wireless networks. The on-board 802.11 wireless radio tunes into each of the possible thirteen channels, sends a request probe and waits for any response from broadcasting access points. The report is mined to find a previously selected network based on its Service Set Identifier (hereafter SSID). When a matching SSID is found, the routine extracts the RSSI value and remaps it into a light brightness value ranging from 0 to 100. Such information is then passed onto the LED strip to produce the mapped light value.

A series of initial tests were performed to establish the efficacy of using the mapping device in the context of long-exposure photography. The instrument was handheld and moved across the space in front of a DSLR camera. In an initial period of trial, we decided to map signal strength values to light brightness. This translation proved unable to depict clearly the changing nature of the values. Thus, the translation routine was modified to employ a five colour gradient, which associated the linear scale of receive signal strength values to colour warmth. The selected scheme was based on the perceptual principle of colour semantics. For example, colours located near to the red hue are generally regarded as conveying warmth, which can be explained to their relation to the object of fire. Red is therefore associated with protection and survival, and standing as a diametrical opposite to blue, a colour associated with cold and death. Such metaphorical connections of temperature and colour hue have served to associate a gradient of red to blue with data structures which imply a linear progression. Under this logic, higher values in RSSI are mapped into a red hue, whilst weaker values in received strength were represented in colder hues. Following this implementation, a series of photographic explorations was performed to understand the representation possibilities of the translation device.

Figure 4 shows a scene where an Android device is place on top of a couch. The phone is configured to broadcast a personal hotspot, a low powered Wi-

Fi network intended to share a mobile data connection within a small spatial area. It can be observed from the image that the colour scheme succeeds in transmitting the differences in RSSI values, depicting a changing field around the emitting antenna.

Yet, the significance of this early exploration lies not in the success of mapping an expected model of signal spread, but on the difficulties encountered throughout the process. Figures 5 and 6 show an attempt to represent the geometry of the wireless field around a standardised field of a cell phone. There is, however, an uneven distribution observed in focal points where a difference in signal strength can be observed. The images are dominated not by colour hues, but by often shaky path of the hand held device – in other words the choreography of the user.

A further complication arises in the delay produced by the speed in which the mapping is performed and the sequence of active scanning. As has been explained previously, active scanning involves a process of broadcasting a request to probe any broadcasting station in all thirteen possible channels. The process is dependant upon the conditions of each channel. If a broadcast is already in progress within a specific channel, the device needs to wait before broadcasting its probe. Factored by all channels, each scanning process can vary greatly in the time it takes to perform. Generally speaking, the translating device takes two seconds in yielding the scanning results. In the context of the experiments undertaken, this meant that signal strength values from a particular spot where being translated and represented elsewhere, as the instrument was being dragged across space in periods of time shorter than it takes to capture the values.

This mismatch between capture and visualisation prompted a second phase in the development of the Kirlian device. In order to control the points at which data was being captured and visualised, a physical interrupt button was implemented in the circuitry. In the algorithmic routine, this meant that the

active scan would only be initiated when the performer triggered the button. The translating device would only map the values to the LED strip once the scanning routine had been completed. Lights would remain on for two seconds, indicating to the performer that a new scan had to be initiated. Figures 7 and 8 correspond to the exploration performed using this modified version of the scanning sequence.

The capturing process varied slightly due to the implementation of the interrupt button. The performer would need to press the button, wait for the scanning routine to complete and then move the device once the LED had turned on. The effect of such procedure can be observed in, for instance, in Figure 7. There is a clear indication of the point of disjuncture in the horizontal path followed by the device.

The series of photographic experimentation revealed a series of unanticipated complications to the exercise of mapping 802.11 wireless networks. They stress how dependant the resulting images are on the performance through which values are captured. Not only the movements followed by the performer had an immediate effect on the textures rendered by the light trails, but they also affected the way in which data was being captured and represented. A careless, rapid movement would create offsets in the generated landscape. This can be observed in Figure 5 and 6, where the hot spots of signal strengths, which would be expected to fall in close proximity to the broadcasting station, are shifted to the middle part of the vertical trail. The same effect is observed in Figure 8, where the hot zone is slightly offset towards the couch armrest.

In later explorations, we also produced a series of pictures with the background of the campus of Newcastle University and the Architecture Planning and Landscape buildings (Figures 9 to 11). These images raised questions over the status of this type of visualization. If we consider the Wireless network as an object, in the sense provided by Object-Oriented

Philosophy of an unified reality that cannot be reduced neither to its pieces nor to its appearances and effects (Harman 2002), and the performer and mapping device as objects as well, the resulting images are not representations but a new object which arises out of the relations and tensions between the three objects in play. The resulting image then does not provide an accurate or objective rendition of the spatial spread of a wireless network, but presents the tensions between means of mapping the network, one aspect of its physical properties and the author of the image.

This tension is further revealed in the public response to the images. As was the case with the Immaterials project, the Wireless Spectres images have gained substantial coverage in mostly online, popular media including the BBC, Wired and the blog of Fast Company (Editor 2014; Brownstone 2014; Sintson 2014) in addition to many other technology media outlets (O'Callaghan 2014; McDonald 2014; Zipkin 2014; Chartier 2014; Project 2014; Pooiee 2014). This coverage is revealing both in terms of the journalistic interpretation of the work and the comments generated by the articles.

Contrasts can be drawn between the coverage of the *Immaterials* project, which is often framed in terms of objective measurement and cartography (Timo Arnall 2011; Timo Arnall 2013). The project therefore tends to be regarded by the audience as an exercise of neutral observation and a straightforward revealing of the invisible. For example, in the comment thread at the YOUrban and Near Field website, where one of the authors penned articles on the project, readers discuss the project mainly in technical terms, occasionally suggesting small changes to the representation technique. The project is considered to be transparent. Elsewhere, for example, the project is analysed as an innovative technique of data visualization, which '*reduces the unpredictable to the explicable*' (Editor 2013).

In contrast, the *Digital Ethereal* project seems to encourage debate on what wireless are, and how exist in the world. The project has prompted over 200 comments across different publications, and has been share up to 40,000 times in social media to the time of writing. Of 46 comments left IFLScience article (Luntz 2014) on the project for example, 26 engaged in a debate on how precise the representations were. Whilst some readers claimed that it was not a scientific depiction, other replied by stating that the pictures prompted speculation and curiosity on the technology. The Wired (Sintson 2014) audience in particular debated whether this was art or science and questioned the validity of the article with one commenter dismissing the validity of the images based on our use of the Kirlian name for the device itself.

The way in which the images operate as probes to question and speculate on the materiality of wireless can be attested in the playfulness of its editorials. One article was headed—'Here comes the Wi-Fi ghostbusters' (Maturana 2014). In other cases, there are direct references to the notion of *Ghost in the machine: 'In his series of oddly haunting photographs, researcher and artist (…) has found the ghost in the machine. Or maybe it's the machine in the ghost'* (McDonald 2014)*;* a piece titled '*A Machine Is Visualizing The Ghostly WiFi Waves That Surround Us'* (Sokol 2014)*;* an article with the opening line *'The ghost out of the machine?'* (Starr 2014)*.*

The exploration for language to describe different materialities can be seen also in associations (and given the context of wireless technologies described above, a re-association) of the work with the human body. One of the pieces, for instance was headed as '*This architect is wearing his Wi-Fi Signal'* (Brownstone 2014)*.* The images also prompted readers across a number of outlets to discuss about health concerns regarding wireless technologies. In the online version of the Daily Mail article (O'Callaghan 2014) covering the project, around 70% of the comments discussed health concerns due to radiation exposure. The story was also covered in online publications

specifically focused in Electromagnetic Hypersensitivity, and taken to represent how a person suffering the disease experiences electromagnetic field propagation (Burrell 2014). Additionally, the project´s website included a contact form in which visitors were encourage to contact the authors to leave their impressions on the projects. Some of the correspondence received through this medium discusses mystical notions of wireless technologies, as well as concerns on how wireless technologies affect human health.

5. Conclusion

In this paper we have presented a case for a cultural reading of wireless networks, and specifically of Wi-Fi technologies. As technologies like Wi-Fi become increasingly ubiquitous as a material, but largely intangible influence on our public and private spaces, finding ways of revealing their modes of operation become increasingly important. Revealing their nature is not, however, a simple exercise of scientific measurement or of 'visualising the invisible'. It is about revealing their culturally rooted nature and finding modes of representation which both reveal their invisibility, and are critical of their context of operation and existence.

In the case of the Digital Ethereal project, we sought a creative exploration of an existing practice by extending the approach taken in the Immaterials project. In addition however, we deliberately drew attention to the means of production and suggested, through the composition of the image and the naming of the capture device (the Kirlian Device) creating an association with 19th century mysticism and ghosts. The resulting images were received well by popular media outlets, but were broadly interpreted both by the journalist and members of the public with regards to their impact on the human body and mystical narratives. The images triggered debates about the scientific validity of the photographs as visualisations, and fears about electromagnetic sensitivity. The images do not provide maps of the territory of Wi-Fi, rather they begin to open up a new design space which considers an alternative cultural representation of technologies – stripped of pseudo-objectivity. They

represent alternative ways of representing technologies which are often considered to be banal. Rather than Weiser's dream of technologies of disappearance, the images propose, through wireless, a technology of many appearances.

References

Arnall, T. 2011. "Immaterials: Light Painting WiFi | Touch." *Near Field Touch*. http://www.nearfield.org/2011/02/wifi-light-painting.

Arnall, Timo. 2011. "Immaterials: Light Painting WiFi." *Touch*. http://www.nearfield.org/2011/02/wifi-light-painting.

———. 2013. "The Immaterials Project." *Elastic Space*. http://www.elasticspace.com/2013/09/the-immaterials-project.

Barad, Karen. 2006. "Posthumanist Performativity : Toward an Understanding of How Matter Comes to Matter." CHAP. In *Belief, Bodies, and Being: Feminist Reflections on Embodiment*, edited by Deborah Orr. Rowman & Littlefield Publishers.

Benford, Steve, Andy Crabtree, and Martin Flintham. 2006. "Can You See Me Now?" *ACM Transactions on Computer-Human Interaction (TOCHI)* 1 (March): 100–133.

Blanco, M P, and E Peeren. 2013. *The Spectralities Reader: Ghosts and Haunting in Contemporary Cultural Theory*. BOOK. Bloomsbury Publishing.

Bolter, J D, and R Grusin. 2000. *Remediation: Understanding New Media*. BOOK. MIT Press.

Bowler, P J. 2010. *Reconciling Science and Religion: The Debate in Early-Twentieth-Century Britain*. BOOK. Science and Its Conceptual Foundations S. University of Chicago Press.

British Council. 2014. "Ray Lee." *British Council, Theatre and Dance*. http://theatreanddance.britishcouncil.org/artists-and-companies/profiles/ray-lee/.

Brownell, Blaine. 2014. "Chapter 5 - Manipulating the Material Code: The Transformation of Material Meaning in Contemporary Japanese Design A2 - Karana, Elvin." CHAP. In , edited by Owain Pedgley and Valentina B T - Materials Experience Rognoli, 51–61. Boston: Butterworth-Heinemann. doi:http://dx.doi.org/10.1016/B978-0-08-099359-1.00005-9.

Brownstone, Sydney. 2014. "This Architect Is Wearing His Wi-Fi Signal." *Fast Company Exist*.

Burrell, Lloyd. 2014. "WiFi Radiation – New Device Makes It Visible At Last." *Electric Sense*.

Chan, Casey. 2013. "What the World Would Look Like If You Could Actually See Wi-Fi Signals." *Gizmodo*.

Chartier, Mathieu. 2014. “Des Photographies Des Ondes WiFi, Ou Presque.” *PC World France*. http://www.pcworld.fr/high-tech/actualites,luis-hernan-digital-ethereal-kirlian-device,549919,1.htm?comments=1.

Ciesielska, IL. 2009. “Images of Corona Discharges as a Source of Information about the Influence of Textiles on Humans.” *AUTEX Research Journal* 9 (March). http://ww.bio-well.eu/assets/files/papers/Textiles/2009 Ciesielska Textiles.pdf.

Coyne, R. 2010. *The Tuning of Place: Sociable Spaces and Pervasive Digital Media*. Book. MIT Press.

D.B., Jonathan. 2011. “Immaterials: Light Painting Wifi by Timo Arnall + Jorn Knutsen + Einar Sneve Martinussen.” *Design Boom*. http://www.designboom.com/design/immaterials-light-painting-wifi-by-timo-arnall-jorn-knutsen-einar-sneve-martinussen/.

Dade-Robertson, M. 2011. *The Architecture of Information: Architecture, Interaction Design and the Patterning of Digital Information*. Book. Routledge.

———. 2013. “Architectural User Interfaces: Themes, Trends and Directions in the Evolution of Architectural Design and Human Computer Interaction.” JOUR. *International Journal of Architectural Computing* 11 (1): 1–20. doi:10.1260/1478-0771.11.1.1.

De Vicente, J L, H Harger, and J Perello. 2012. *Invisible Fields: Geographies of Radio Waves*. Book. Actar (NY).

Dunne, A. 2006. *Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design*. Citeulike:BOOK. London, England: The MIT Press.

Dunne, A, and F Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. BOOK. MIT Press. https://books.google.co.uk/books?id=9gQyAgAAQBAJ.

Editor. 2013. “Immaterials: Light Painting WiFi.” *Significance* 10 (4): 38–39. doi:10.1111/j.1740-9713.2013.00683.x.

———. 2014. “Newcastle Student Brings to Life Invisible Wireless Networks.” *BBC News*. http://www.bbc.co.uk/news/uk-england-tyne-27501051.

Graham, S, and S Marvin. 2002. *Telecommunications and the City: Electronic Spaces, Urban Places*. BOOK. Taylor & Francis.

Greenfield, A, and M Shepard. 2007. *Urban Computing and Its Discontents*. Book. Situated Technologies Pamphlets. New York, New York, USA: The Architectural League of New York.

Haque, Usman, Bengt Sjölen, and Adam Somlai-Fischer. 2007. “Wifi Camera Obscura.”

Harman, Graham. 2002. *Tool-Being. Heidegger and the Metaphysics of Objects*. First. Chicago and La Salle, Illinois: Open Court.

Hill, Dan. 2009. “Wi-Fi Structures and People Shapes.” *Habitar, Bending the Urban Frame. Mediateca Expandida.* 1 (3): 98–100.

———. 2012. “21st Century Gestures Clip Art Collection.” BOOK. In *Curious Rituals: Gestural Interaction in the Digital Everyday*, edited by N Nova, K Miyake, W Chiu, and N Kwon.

Holmes, Kevin. 2011. “Light Painting Visualizations Of Oslo’s WiFi Network | The Creators Project.” *Vice Creators Project*. http://thecreatorsproject.vice.com/en_uk/blog/light-painting-visualizations-of-oslos-wifi-network.

Husbands, Lilly. 2013. “The Meta-Physics of Data: Philosophical Science in Semiconductor’s Animated Videos.” Article. *MIRAJ, Moving Image Review & Art Journal* 2 (2). Intellect: 198–212.

Ishii, Hiroshi, Craig Wisneski, Scott Brave, Andrew Dahley, Matt Gorbet, Brygg Ullmer, and Paul Yarin. 1998. “ambientROOM: Integrating Ambient Media with Architectural Space.” CONF. In *CHI 98 Cconference Summary on Human Factors in Computing Systems*, 173–74. ACM.

Kleinman, Adam. 2013. “Intra-Actions.” *Mousse*, no. 34: 76–81.

Leonardi, Paul M. 2010. “Digital Materiality? How Artifacts without Matter, Matter.” JOUR. *First Monday* 15 (6). http://firstmonday.org/ojs/index.php/fm/article/view/3036/2567.

Lillegerd, Hanson. 2007. “Inside Making: Living in the Material World.” *Studies in Material Thinking* 9: 14.

Lodge, O. 1909. *The Ether of Space*. BOOK. Harper’s Library of Living Thought. Harper & Brothers.

Luntz, Stephen. 2014. “The Invisible Beauty of Wireless Networks.” *IFLScience*.

Manzini, E. 1995. *The Material of Invention: Materials and Design*. BOOK. MIT Press.

Martinussen, Einar Sneve. 2011. “Immaterials: Light Painting WiFi.” *YOUrban*. http://yourban.no/2011/02/22/immaterials-light-painting-wifi/.

———. 2012. “Making Material of the Networked City.” Book. In *Design Innovation for the Built Environment: Research by Design and the Renovation of Practice*, edited by Michael U. Hensel. Taylor & Francis Group.

Maturana, Jesus. 2014. “Digital Ethereal, Llegan Los Cazafantasmas Wi-Fi.” *Xataka*.

Maxwell, Clark. 1891. “Ether.” BOOK. In *Encyclopædia Britannica (Ninth Edition): A Dictionary of Arts, Sciences, and General Literature*. Supplement to Encyclopædia Britannica (Ninth Edition): A Dictionary of Arts, Sciences, and General Literature. Henry G. Allen Company.

McDonald, Glenn. 2014. “Digital ‘Spectres’ Reveal Invisible, Wireless World.” *Discovery News*. http://news.discovery.com/tech/apps/digital-spectres-reveal-invisible-wireless-world-140516.htm.

McLuhan, M, and Q Fiore. 2011. *The Medium Is the Massage: An Inventory of Effects*. BOOK. Gingko Press GmbH.

Mitchell, W J. 1996. *City of Bits: Space, Place, and the Infobahn*. BOOK. MIT Press.

———. 2003. *Me++: The Cyborg Self And The Networked City*. Book. Mit Press.

Nordby, Kjetil. 2010. “Conceptual Designing and Technology: Short-Range RFID as Design Material.” JOUR. *International Journal of Design; Vol 4, No 1 (2010)*. http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/625/285.

———. 2011. “Between the Tag and the Screen Redesigning Short-Range RFID as Design Material.” The Oslo School of Architecture and Design.

O’Callaghan, Jonathan. 2014. “Whirling Wi-Fi: Vibrant Images Reveal How Wireless Networks Sweep and Surround Us.” *Daily Mail*, June.

“Observatorio, Clara Boj and Diego Diaz.” 2008. *Goethe Institute*. http://www.goethe.de/ins/ee/prj/gtw/aus/wer/boj/enindex.htm.

Pooiee. 2014. “Digital Ethereal: Capturing the Colourful World of Invisible Wireless Networks with a ‘paranormal Camera.’” *Techly*. http://www.techly.com.au/2014/05/30/digital-ethereal-capturing-colorful-world-invisible-wireless-network-paranormal-camera/.

Project, Creators. 2014. “Visualizing the Ghostly WiFi Waves That Surround Us - iQ by Intel.” *IQ Intel*. http://iq.intel.com/visualizing-the-ghostly-wifi-waves-that-surround-us/.

Schön, D.a. 1992. “Designing as Reflective Converstion with the Materials of a Deisgn Situation.” *Knowledge-Based Systems*. http://linkinghub.elsevier.com/retrieve/pii/095070519290020G.

Sconce, Jeffrey. 2000. *Haunted Media: Electronic Presence from Telegraphy to Television*. Book. Console-Ing Passions: Television and Cultural Power. Duke University Press.

Sevtsuk, Andres, Sonya Huang, Francesco Calabrese, and Carlo Ratti. 2009. “Mapping the MIT Campus in Real Time Using WiFi.” Book. In *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*, edited by M Foth, 325–37. IGI Global Research Collection. Information Science Reference.

Sintson, Liz. 2014. “These Weird Rainbow Ghosts Show How Wi-Fi Signals Are Shaped.” *Wired*. http://www.wired.com/2014/07/these-arent-rainbow-ghosts-theyre-wifi-signals-visualized/#slide-id-1209681.

Sokol, Zach. 2014. “A Machine Is Visualizing The Ghostly WiFi Waves That Surround Us.” *The Creators Project, Vice*. http://thecreatorsproject.vice.com/en_au/blog/a-machine-is-visualizing-the-ghostly-wifi-waves-that-surround-us.

Starr, Michelle. 2014. “Invisible Wi-Fi Revealed through Light Graffiti.” *CNet*. http://www.cnet.com/uk/news/invisible-wi-fi-revealed-through-light-graffiti/#ftag=CADf328eec.

Sterling, Bruce. 2011. “Showtime: Timo Arnall, ‘Immaterials: Light Painting

WiFi.'" *Wired*. http://www.wired.com/beyond_the_beyond/2011/02/showtime-timo-arnall-immaterials-light-painting-wifi.

Weiser. 1999. "The Computer for the 21st Century." Article. *SIGMOBILE Mob. Comput. Commun. Rev.* 3 (3). New York, NY, USA: ACM: 3–11. doi:10.1145/329124.329126.

Zipkin, Nina. 2014. "Wi-Fi Revealed Through Stunning Photos." *Entrepreneur*. http://www.entrepreneur.com/article/235217.

Biographies

Luis Hernan
Luis is a designer and doctoral researcher at the School of Architecture, Planning and Landscape at Newcastle University. His research looks at the creation of a new design object, the Digital Ethereal, which speculates on new modes of existence for wireless technologies in the context of interaction design and Architecture.

Martyn Dade-Robertson
Martyn is a Senior Lecturer in the School of Architecture Planning and Landscape at Newcastle University. He has written extensively on the subject of Architecture and Interaction design, most notably through his book: *The Architecture of Information* published by Routledge in 2011.

List of figures

Figure 7—Image produced after the scanning protocol had incorporated an interrupt button. Points of disjoint are clearly observed in the image as nodes of light

Figure 8—Image produced with interrupt button implemented. The vertical trails still shows a mismatch between point of measurement and representation, on top of the left armrest.

Figure 9—Image produced in an interior corridor of the School of Architecture, Newcastle University. [PREFERED REPRODUCTION SIZE: A4]

Figure 10—Image produced outside the school of Architecture, depicting the condition of threshold in Wi-Fi Networks. [PREFERED REPRODUCTION SIZE: A4]

Figure 11—Image produced in interior cafeteria of the School of Architecture. [PREFERED REPRODUCTION SIZE: A4]

Figure 12—Image produced in interior lounge, School of Architecture. [PREFERED REPRODUCTION SIZE: A4]